

**OVERVIEW OF  
NATIONAL RESEARCH COUNCIL  
REPORT  
OZONE-FORMING POTENTIAL OF  
REFORMULATED GASOLINE**

Presentation by

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to

The Oxygenates Blue-Ribbon Panel

May 24, 1999

# **The NRC Committee on Ozone-Forming Potential of Reformulated Gasoline**

## **Task Description**

Assess the use of ozone-forming potential (reactivity) for evaluating and comparing motor vehicle emissions resulting from the use of different blends of reformulated gasoline (RFG)

Consider the potential impacts of using a reactivity approach on expected air-quality benefits of the RFG program, including reduction of VOC, NO<sub>x</sub>, and air toxics emissions, as well as reduction of ozone formation.

Focus on use of oxygenates in RFG, with specific attention to MTBE and ethanol

Include consideration of the following:

- Various approaches for evaluating and comparing ozone-forming potentials of RFGs. (e.g., reactivity factors and grid-based airshed models) for a nationwide program
- Various air quality issues relevant to ozone-forming potential of RFGs (e.g., peak (one-hour) and average (eight-hour) ozone levels; whether CO should be included; and changes in NO<sub>x</sub> emissions
- Sensitivity of evaluations of ozone-forming potential to factors related to fuel properties and variability of vehicle technologies and driving patterns.
- Identify major gaps in existing scientific and technical information and recommend how such gaps might be filled.

## **What the Charge Did Not Address**

- Design and implementation of possible new regulations based on ozone-forming potential of RFG blends
- Domestic sources versus foreign sources of fuel
- Relative energy and cost implications for production of different RFG blends
- Relative health and global environmental impacts
- Use of renewable versus nonrenewable fuels
- Emissions resulting from production, storage, and distribution of various RFG blends
- Emissions from non-road vehicles using RFG
- Effectiveness of oxygenates or other substances for enhancing the octane-value of RFG blends

**Committee on Ozone-Forming Potential of  
Reformulated Gasoline**

**Membership Roster**

**William L. Chameides (Chair)**, Georgia Institute of Technology,  
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Argonne, Illinois

**The NRC Committee's Report:**

***Ozone-Forming Potential of Reformulated Gasoline***

**Contents**

**Preface**

**Executive Summary**

**Chapter 1 Introduction**

**Chapter 2 Ozone Photochemistry**

**Chapter 3 The Concept of Ozone-Forming Potential and  
Its Quantification**

**Chapter 4 Motor Vehicles as a Source of Ozone  
Precursors**

**Chapter 5 Reformulation of Gasoline**

**Chapter 6 The Effects of Reformulated Gasoline on  
Ozone and Its Precursors**

**Chapter 7 Using Ozone-Forming Potential to Evaluate the  
Relative Impacts of RFGs: A Case Study**

## **PRESENTATIONS TO THE COMMITTEE**

Perspectives of the U.S. EPA's Office of Mobile Sources

Chuck Freed, Director, Fuels & Energy Division (retired)

Susan Willis, Manager, Fuel Studies & Standards Group

California's Cleaner-Burning Gasoline; Overview of

California Reformulated Gasoline Program and Reactivity Issues.

Dean Simeroth, California Air Resources Board staff

Council of Great Lakes Governors Study

Dennis Lawler, Illinois EPA

Effect of Oxygen and Reactivity on Ozone Formation

Michael Ward of Swidler and Berlin

Gary Whitten, Systems Application International

Reactivity, Urban Ozone Formation, and RFG

Alan Dunker, General Motors

Real RFG Outperforms Model

Cal Hodge, Chair, Oxygenated Fuels Association

Technical Committee

Comments from Barry McNutt, U.S. Department of Energy

Uncertainties in the Use of Incremental Reactivity Factors

William Cater, University of California at Riverside

Cleaner-Burning Gasoline: An Assessment of Its Impact on Ozone

Lawrence Larsen, California Air Resources Board staff

Impact of MTBE and Reformatted Gasoline on Vehicle Emissions

Robert Harley, University of California at Berkeley

Perspectives of the American Petroleum Institute

Howard Feldman, API

Charles Schleyer, Mobil Corporation

## **Report Reviewers**

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Marc Ross, University of Michigan

Charles Schleyer, Mobil Corporation

Lance Waller, Emory University

Gary Whitten, Systems Application International, Inc.

## **Topics of Committee's Major Findings**

- 1. OZONE-PRECURSOR EMISSIONS FROM GASOLINE-FUELED VEHICLES**
- 2. HIGH-EMITTING MOTOR VEHICLES**
- 3. THE USE OF REACTIVITY IN ASSESSING THE OZONE-FORMING POTENTIAL OF EMISSIONS**
- 4. RELATIVE REACTIVITY AS A MEANS OF COMPARING FUELS**
- 5. REACTIVITY OF CARBON MONOXIDE EMISSIONS**
- 6. OVERALL AIR QUALITY BENEFIT OF RFG**
- 7. EFFECT OF OXYGENATES IN RFG**
- 8. MTBE BLENDS VERSUS ETHANOL BLENDS - EXHAUST EMISSIONS**
- 9. MTBE BLENDS VERSUS ETHANOL BLENDS - EVAPORATIVE EMISSIONS**
- 10. REID VAPOR PRESSURE OF ETHANOL-CONTAINING FUEL**
- 11. USE OF REACTIVITY TO EVALUATE RFGs**
- 12. MODELS USED TO CHARACTERIZE EMISSIONS FROM RFG BLENDS**
- 13. OPPORTUNITY TO TRACK EFFECTS OF PHASE II RFG PROGRAM**



## **1. OZONE-PRECURSOR EMISSIONS FROM GASOLINE-FUELED VEHICLES**

Overall emissions of ozone precursors from gasoline-fueled motor vehicles have substantially decreased in recent decades, largely as a result of government mandates and industry's development and use of new emission controls on motor vehicles.

- If projections are correct, potential impact of using RFG on near-ground ozone will decrease with time
- Air quality models suggest that the RFG program reduces ozone by a few percent
- It is difficult to attribute a significant relationship between the apparent downward trend in ozone and use of RFG

## **2. HIGH-EMITTING MOTOR VEHICLES**

A sizable portion of the ozone-precursor emissions from gasoline-fueled motor vehicles appears to be associated with a relatively small number of high-emitting vehicles in the United States.

- Most emissions testing of motor vehicles using RFG has been performed on normally functioning vehicles
- Substantial uncertainty on how RFG affects emissions from high-emitting vehicles

### **3. THE USE OF REACTIVITY IN ASSESSING THE OZONE-FORMING POTENTIAL OF EMISSIONS**

The use of reactivity in assessing the ozone-forming potential of VOC emissions has reached a substantial level of scientific rigor, largely as a result of research sparked by policy making in California over the past several decades.

- Assessment of reactivity is most appropriate for VOC-limited areas
- Reactivity factors could be applicable for 8-hour ozone standard just as for 1-hour ozone standard
- As currently used, reactivity is of limited value in NO<sub>x</sub>-limited regions

#### **4. RELATIVE REACTIVITY AS A MEANS OF COMPARING FUELS**

**The most robust reactivity measures for comparing emissions from different sources are the so-called relative-reactivity factors, but they are often uncertain and of limited utility for comparing similar RFG blends.**

- Uncertainty in relative reactivity for emissions, such as those arising from motor vehicles, is generally about 15-30%.**
- Because reactivity of emissions from motor vehicles using various RFG formulations tends to be similar and emissions composition so variable, the reactivity approach is sometimes of limited utility.**

## **5. REACTIVITY OF CARBON MONOXIDE EMISSIONS**

Carbon monoxide (CO) in exhaust emissions from motor vehicles contributes about 20% to the overall reactivity of motor-vehicle emissions.

- Contribution of CO to ozone formation should be included in assessments of RFG effects
- As VOC emissions continue to decrease, CO emissions might become a proportionally greater contributor to ozone formation

## **6. OVERALL AIR QUALITY BENEFIT OF RFG**

Emissions tests, tunnel studies, and remote-sensing of tail-pipe exhaust indicate that RFG usage can cause a decrease in both the exhaust and evaporative emissions from motor vehicles.

- Major contributors to decreased emissions appear to be the lowering of fuel's RVP and the lowering of sulfur in fuel.
- Despite the emission reductions, the overall effect of RFG on ozone air quality is expected to be difficult to discern.

## 7. EFFECT OF OXYGENATES IN RFG

The use of commonly available oxygenates in RFG has little impact on improving ozone air quality and has some disadvantages.

- The decrease, if any, of the mass of VOC and CO exhaust emissions, and their combined reactivity, that are attributable to oxygenates appears to be quite small
- Some data suggest that oxygenates can lead to higher NO<sub>x</sub> emissions
- Most significant advantage of oxygenates in RFG appears to be displacement of some air toxics (e.g., benzene) from RFG
- MTBE blends might increase formaldehyde emissions
- Ethanol blends might increase acetaldehyde emissions

## **8. MTBE BLENDS VERSUS ETHANOL BLENDS - EXHAUST EMISSIONS**

The reactivity of the exhaust emissions from motor vehicles operating on ethanol-blended RFG appear to be lower--but not significantly lower--than the reactivity of the exhaust emissions from motor vehicles operating on MTBE-blended RFG.

- Available data showed no statistically significant difference (at the 95% confidence level) between RFGs blended with MTBE or ethanol in mass of VOC or NO<sub>x</sub> emissions
- No significant difference between MTBE and ethanol blends in reactivity of VOC exhaust emissions
- CO emissions are somewhat lower for ethanol-blended RFG



## **9. MTBE BLENDS VERSUS ETHANOL BLENDS - EVAPORATIVE EMISSIONS**

Both the mass and reactivity (mass of ozone per mile) of evaporative emissions from motor vehicles using ethanol-blended RFG were significantly higher than from motor vehicles using MTBE-blended RFG.

- Higher evaporative emissions of ethanol-blends were likely due, at least in part, to a higher RVP (1 psi)
- Increase in reactivity of evaporative emissions of ethanol blends outweighs small decrease in reactivity of exhaust emissions

## **10. REID VAPOR PRESSURE OF ETHANOL-CONTAINING FUEL**

On the basis of finding 9 above, it appears likely that the use of an ethanol-containing RFG with an RVP that is 1 psi higher than other RFG blends would be detrimental to air quality in terms of ozone

- This is consistent with CARB's findings

Note:

- Conclusion is based on test data from normally functioning motor vehicles, which might or might not, have underestimated benefits of ethanol blends on high emitting vehicles
- Overall impact on ozone of allowing ethanol containing fuel would likely be quite small in any case.

## **11. USE OF REACTIVITY TO EVALUATE RFGs**

The committee sees no compelling scientific reasons at this time to recommend that fuel certification under the RFG program be evaluated on the basis of the reactivity of the emission components.

- Available data showed that the fundamental conclusion concerning the choice of one fuel over another on the basis of relative potential air-quality benefits is not altered by switching from a mass-emissions metric to a reactivity-weighted metric.

## **12. MODELS USED TO CHARACTERIZE EMISSIONS FROM RFG BLENDS**

The models currently used to inform regulatory decision making--by quantifying emissions from motor vehicles that use RFG blends--are problematic.

- Those models are based on a small sampling of motor vehicles
- Capability of reflecting actual emissions needs to be improved

### **13. OPPORTUNITY TO TRACK EFFECTS OF PHASE II RFG PROGRAM**

The introduction of Phase II of the federal RFG program in 2000 offers a unique opportunity to track and document the impact of a new ozone-mitigation program.

An atmospheric measurement program is needed to assess the impact of Phase II RFG on

- Precursor emissions from on-road and non-road motor vehicle fleet, as well as their ozone-forming potentials
- Ambient concentrations of ozone and its precursors